(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 February 2004 (05.02.2004)

PCT

(10) International Publication Number
WO 2004/012482 A2

(51) International Patent Classification[7]: H05F

(21) International Application Number:
PCT/GB2003/003312

(22) International Filing Date: 30 July 2003 (30.07.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0217666.7 31 July 2002 (31.07.2002) GB

(71) Applicant *(for all designated States except US)*: **AEA TECHNOLOGY PLC** [GB/GB]; 329 Harwell, Didcot, Oxfordshire OX011 9PT (GB).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **SHILTON, Mark, Golder** [GB/US]; 5 Brothers Lane, Chelmsford, MA 01824 (GB).

(74) Agents: **MANSFIELD, Peter, Turquand** et al.; Accentus plc, Patents Dept., 329 Harwell, Didcot, Oxfordshire OX11 9PT (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: HIGH VOLTAGE DC SURFACE STATIC REDUCTION DEVICE

(57) Abstract: A surface static reduction device comprises a gun (1) defining an ionising chamber (16) in communication with an outlet nozzle (11), and means to provide a flow of air through the ionising chamber. Within the ionising chamber (16) are positive and negative corona discharge points (22), connected to a high voltage supply cable arranged to supply high voltages to the electrodes, the voltage to be supplied to the positive electrode being of larger magnitude than that to be supplied to the negative electrode. High value resistors (27) are provided within the gun between the supply cable (7) and the positive and negative electrodes (22), each with a resistance in the range 40-500 MΩ. Such a device can be intrinsically safe even for use in an inflammable atmosphere.

WO 2004/012482 A2

High Voltage DC Surface Static Reduction Device

Background To The Invention

The present invention relates to a device which reduces or preferably eliminates static electricity from the surfaces of electrically charged objects or materials, which may be used, processed, stored or otherwise handled in potentially hazardous locations where a spark caused by an electrostatic discharge may cause a serious fire, explosion or injury.

Static electrification occurs whenever electrically insulating materials move, rub against or separate from one another. This occurs particularly in clean, dry conditions when charges which have accumulated cannot easily find a conducting path to ground. Any surfaces can be involved such as solid/gas, solid/liquid, solid/solid and liquid/gas. The clean and dry conditions, the high speed of modern industrial processes and the prevalence of insulating materials throughout industry provide perfect conditions for static electrification to occur. The surface finish of materials undergoing coating processes may be affected by electrostatic fields. In the automotive industry for example, millions of US dollars are lost each year due to faulty paint-work, caused by dust inclusions arising from paint dust, which may be attracted to surfaces by strong electrostatic forces from charged body panels. Or non-random orientation of metallic particles in paint can result from electrostatic fields, which causes poor and variable surface quality. This is a common problem and one which is very difficult to solve safely. The paint-spraying environment is extremely hazardous, involving toxic and highly flammable solvent vapours, aerosols and dusts. Voltages on car panels can reach dangerous levels well above 20,000 V at

times after cleaning and polishing operations. At this level it is possible for electrical breakdown of an air gap between an electrically charged object or person and a grounded surface to occur, so a spark is possible.

Various different types of static eliminators are known, and all operate using the same basic principle. They make the air in the space between a charged object and a grounded conductor conduct electricity by ionizing the air. This allows charge to leak to ground efficiently and rapidly by ionic conduction through the air. The effectiveness and suitability of a static eliminator depends on its dissipation current, i.e. the rate at which it can dissipate static charge. This is related to the number of ion pairs per unit time it can produce and its ability to direct the ions to where they are needed most. The most powerful static eliminators are DC high voltage devices. These eliminators apply a high voltage, usually of the order of 5 kV, to positive and/or negative corona discharge tips, which produce a stream of positive and/or negative ions away from the tips to discharge static electricity from the surfaces of insulating objects nearby. Static eliminators need be robust to withstand tough industrial environments and to be "intrinsically safe". This means the high voltage power used to operate them must not be capable of causing a fire, explosion or other hazard.

In applications where ions are required at long distances away from the devices, fan blowers and compressed air devices are used to blow ions to where they are needed. For example, compressed air driven radioactive air guns have been used to deliver high velocity ionized air to surfaces from which dust particles must be removed (e.g. prior to painting car body panels). High voltage electrically powered static eliminators are

not commonly used for this sort of application because of the inherent risks associated with the use of high voltage electrical equipment in such potentially hazardous environments where volatile or explosive solvents and dusts can be found.

However the use of radioactive devices is subject to strict regulation, and is not always acceptable. It is an objective of the current invention to provide an intrinsically safe high voltage electrical air gun to replace radioactive units on the market, which fully complies with regulations governing the use of high voltage equipment in potentially explosive atmospheres, so that the regulatory disadvantages associated with the radioactive air gun are avoided. The current invention utilises a combination of known high voltage DC corona discharge technology, combined with spark-suppression circuitry which is encapsulated within a light-weight, hand-held air gun unit capable of high static discharge performance and yet intrinsically safe for use in hazardous environments.

The high voltage DC air gun described in this invention can also be used for a multitude of other static elimination applications and is not limited to use in paint surface preparations.

Main Principle Of Operation

When a high voltage is applied to an array of sharp points, a corona discharge is set up when the voltage gradient exceeds the dielectric breakdown threshold of the air above the points. This occurs when the voltage exceeds about 4 kV, depending on the size, shape and spacing of the points.

Applying a high positive or negative voltage to a point array ionizes the air above the points and generates a corona discharge current consisting of positive and negative ions. Ions of one sign stream away from the points under the influence of the electrostatic field. Ions of the other sign are attracted. Nearby objects can be efficiently neutralized. The ion current is predominantly of one sign, and so may counter-charge objects as well as neutralize them. By using both positive and negative points, positive and negative ion currents are produced, so reducing the risk of leaving residual counter-charges.

A drawback of electrically powered high-voltage static eliminator equipment is that devices may not be intrinsically safe, and may not therefore be suitable for use hazardous areas containing flammable or potentially explosive materials. The high voltage power supplies, cables and corona points themselves may render devices unsafe in such areas. To mitigate this problem, electrical devices may incorporate spark suppression circuitry, which can reduce the risk of sparks, or at least lower the energy of sparks below a safety threshold. Spark suppression circuits have been designed to detect sudden discharges and switch off power or to quench sudden changes in the ambient state of circuits so as to prevent a spark. Circuitry required to suppress sparks in DC equipment differs from the circuitry required for AC devices.

Accordingly the present invention provides a surface static reduction device comprising means to define an ionising chamber in communication with an outlet nozzle, and means to provide a flow of air through the ionising chamber to emerge from the outlet nozzle, positive and negative electrodes within the ionising chamber defining

corona discharge points, the device being connectable to an air supply hose and being connectable to a high voltage supply cable arranged to supply high DC voltages to the electrodes, the voltage to be supplied to the positive electrode being of larger magnitude than that to be supplied to the negative electrode, and electrical connections between the cable and the positive and negative electrodes, and wherein each said electrical connection includes an electrical resistor with a resistance in the range 40-500 MΩ.

The values of the resistors and the voltages applied to the electrodes are critical to the performance of the device. Preferably the resistors are of resistance between 40 and 100 MΩ most preferably about 50 MΩ. If the resistance is greater than 500 MΩ the corona discharge current will be so low in normal operation that device performance will be significantly impaired. At the other extreme, if the resistance were to be less than about 30 MΩ there would be a slight risk that a spark of sufficient energy to ignite a highly volatile gas mixture could occur. The value of the resistors is selected to ensure that if the discharge electrodes were inadvertently shorted to ground, and a spark occurs, the maximum power capable of being drawn through the resistors is too low to generate a spark of enough energy to ignite an explosive gas mixture. The resistors must be close to the electrodes, so the capacitance of the connection between them is small; preferably the resistors are within the device, but they might instead be part of an electrical cable connector module outside the device.

This very high value of resistance is considerably higher than that required to prevent the risk of shocks to operators (for which a short-circuit current less than

about 5 mA is considered acceptable), and its introduction does decrease the ion current. But there is less ion recombination in the chamber, and the number of ions in the emerging airflow remains high enough for satisfactory operation. It may be desirable to increase the voltage slightly at the power supply, to partly compensate for the voltage drop across the resistor. (In contrast, an ion source using a pulsed DC or an AC power supply is inherently less powerful because ions are not generated continuously, so use of such a high series resistor would reduce the ion current to below a useful value).

Preferably the voltage to be supplied to the positive electrode is in the range 4.6 - 6.6 kV, more preferably 5.1 - 6.1 kV, for example +5.6 kV; preferably the voltage to be applied to the negative electrode is in the range 3.9 - 5.9 kV, more preferably 4.4 - 5.4 kV, for example -4.9 kV, these voltages being relative to ground potential. In any event, the difference in the magnitude of the voltages should be in the range 300 - 1100 V, more preferably between 500 V and 900 V, for example 700 V, with the voltage supplied to the positive electrode being larger than that supplied to the negative electrode.

The device may be a hand-held device, or may be supported on a mechanical support; in either case it may be referred to as a gun. Preferably initiation of an air flow through the ionising chamber is arranged to cause subsequent initiation of the high voltages to the electrodes. This provides additional safety, in that any potentially explosive or flammable material within the ionising chamber is blown out of the gun before any high-voltage power is applied. Furthermore, erosion of the electrode tips is suppressed, which would be caused if electrical power was applied without airflow, owing to

high discharge currents being set up between the tips of the electrodes within the ionising chamber. Preferably the gun incorporates a trigger to initiate operation.

Preferably the outlet nozzle carrying air from the ionising chamber is of larger diameter than the diameter of the inlet through which the air is supplied to the chamber. For example the outlet may be between 1.2 and 1.4 times the diameter of the inlet. This ensures that if an operator applies too high an air pressure from the air pressure supply, the ionising chamber does not become over-pressurised. The airflow is choked by the inlet rather than the outlet, and the high air pressure is restricted to the air hose and not to the ionising chamber. This ensures consistent device operation over a wide range of input air pressures, which may range typically from about 0.5 to about 3.0 bar above atmospheric pressure.

Description Of The Invention

The present invention will now be further and more particularly described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a diagrammatic block diagram of a static elimination device; and

Figure 2 shows a side view, partly in longitudinal section, of the ionising gun of the device of figure 1.

Referring now to the block diagram of figure 1, an air gun 1 is connected via a compressed air line 2 to an air flow sensor 3 and to a compressed air supply 4, which blows compressed air through the air gun 1 when the trigger 17 of the gun 1 (shown in figure 2) is operated.

When the air flow sensor 3 detects air flowing through the airline 2, a signal is sent via a sensor output circuit 5 to a high voltage power supply 6, which signals the power supply 6 to switch on the high voltage power to the air gun 1 via a high voltage power cable 7 containing positive and negative power leads, which supply positive and negative voltages to two tungsten corona wire points 22 (shown in figure 2). The air-flow sensor 3 operates to ensure that power to the device is only present when air is flowing. This acts as an additional safety feature to ensure the device cannot be left switched on unless someone is operating it, and it significantly reduces erosion of the electrodes, which occurs more rapidly when there is no air flow through the gun 1. The high voltage power supply 6 may have additional high voltage outputs 10 capable of powering more than one static elimination device. The mains power supply 8, the high voltage power supply 6 and the air compressor 4 are all located outside the hazard area 9. All the other components and connections are located inside the hazard area 9. This configuration of equipment has the advantage that only the air gun 1, cables 5 and 7, and flow sensor 3 need to meet stringent hazardous area electrical safety standards.

Referring now to figure 2, the gun 1 is shown in more detail, partly in section. An air outlet nozzle 11 is of generally conical shape, and defines an air outlet duct 12 of internal diameter 6.4 mm, and also defines six, radial pressure release holes 13. The nozzle 11 is connected to one end of a tubular plastic block 14 defining an ionising chamber 16. The ionising chamber 16 is supported by a handle 20, which directs compressed air from the compressor 4 via an air inlet tube 21 of internal diameter 5.0 mm into the ionising chamber 16.

Within the ionising chamber 16 are two tungsten wire emitters 22 or electrodes, each of which consists of a wire bent into the shape of a U or a V to define two wire tips. These face in the general direction of the air-flow and are positioned equidistant from but either side of the central axis of the ionising chamber 16. They are connected to the high voltage power cable 23 and bonded within a suitable electrically insulating high dielectric support material 24, which is located co-axially within the ionising chamber block 14. Through the centre of the electrically insulating support 24 passes the air inlet tube extension 26, which connects to the compressed air line 2 via the handle 20.

A resistor 27, rated for up to at least 9 kV and 0.5 W, preferably rated for 10 kV and 1.0 W, is connected in series with each of the two power leads 28, 29, one to the positive and one to the negative wire emitters 22. Each resistor 27 (only one is shown) is individually potted in electrically insulating potting compound and further encapsulated in insulating heat-shrink sleeving 30. The pair of potted and encapsulated resistors 27 is then further potted into a recess 31 in the gun handle 20 in further electrically insulating potting compound. The potting and encapsulation of all the critical high-voltage components and connectors is carried out so as to ensure there is minimal tracking of current and voltage anywhere within the device and to ensure high voltage components are not exposed to any hazardous area conditions. A tough and durable, screened, high voltage power cable 7 carries power from the high voltage power supply 6 to the resistors 27. The proximity between the resistors 27 and the corona wire emitters 22 minimises the capacitance within the gun 1 and therefore the amount of electrical energy which can be stored within the gun 1.

The values of the resistors 27 and the voltage applied to the corona wire emitters 22 are critical to the performance of the device. These are carefully selected to ensure the device operates safely in a mode which cannot generate a spark in a volatile and explosive atmosphere, whilst delivering a high corona discharge current in normal operation. In the preferred embodiment the voltage supplied to the positive emitter wire 22 is +5.6kV, and that supplied to the negative emitter wire 22 is -4.9kV. The approximately 700V optimal difference ensures that the corona currents from each emitter 22 are approximately equalised (balanced). The tips are made using 0.3 mm diameter square cut tungsten wire "U"s (or "V"s) in the preferred embodiment of this invention.

The value of each resistor 27 is such that if the corona emitters 22 are inadvertently shorted to ground and a spark occurs, the maximum power capable of being drawn is too low to generate a spark of enough energy to ignite an explosive gas mixture; nevertheless the corona discharge currents are not so low as to impair operation. In the preferred embodiment each resistor 27 is of resistance 50 MΩ.

When the trigger 17 on the handle 20 is depressed, a mechanical air valve opens and allows compressed air from the compressor to pass through the gun handle 20. The air-flow sensor 3 detects air flow in the compressed air line 2 and sends a signal to the DC power supply 6, which then applies high voltage power to the corona emitters 22 as outlined above.

Both positive and negative ion streams are generated inside the cavity of the ionising chamber 16 by the two corona emitters 22. These stream away from the tips and turbulently mix with the compressed air passing through

the air gun 1 where they are blown out of the ionising chamber 16 via the air nozzle 11. The diameters that are used in the preferred embodiment of the device are 6.4 mm for the air outlet diameter and 5.0 mm for the air inlet diameter (or alternatively 6.0 mm for the outlet and 4.5 mm for the inlet), whilst the internal diameter of the ionising chamber 16 is 22mm.

Claims

1. A surface static reduction device comprising means to define an ionising chamber in communication with an outlet nozzle, and means to provide a flow of air through the ionising chamber to emerge from the outlet nozzle, positive and negative electrodes within the ionising chamber defining corona discharge points, the device being connectable to an air supply hose and being connectable to a high voltage supply cable arranged to supply high DC voltages to the electrodes, the voltage to be supplied to the positive electrode being of larger magnitude than that to be supplied to the negative electrode, and electrical connections between the cable and the positive and negative electrodes, and characterised in that each said electrical connection includes an electrical resistor with a resistance in the range 40-500 MΩ.

2. A device as claimed in claim 1 wherein the resistors are of resistance between 40 and 100 MΩ.

3. A device as claimed in claim 1 or claim 2 wherein the voltage to be supplied to the positive electrode is in the range 4.6 - 6.6 kV, and the voltage to be applied to the negative electrode is in the range 3.9 - 5.9 kV, these voltages being relative to ground potential.

4. A device as claimed in any one of the preceding claims wherein the difference in the magnitude of the voltages is in the range 300 V to 1100 V.

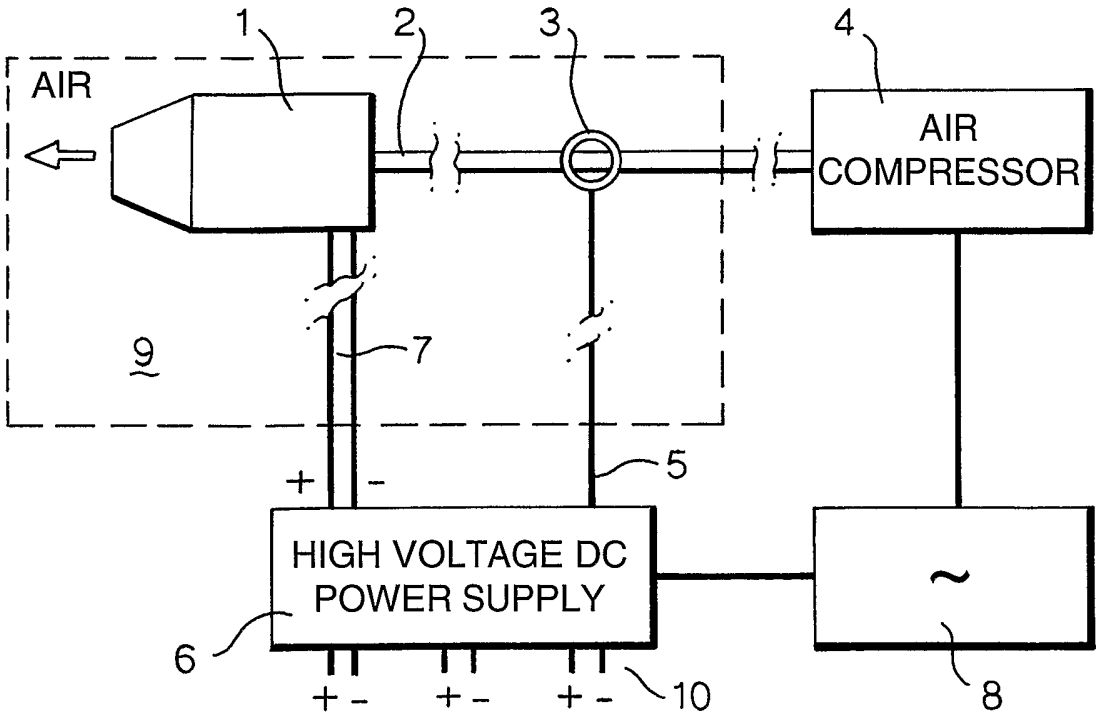
5. A device as claimed in any one of the preceding claims wherein high voltages are provided to the electrodes only after initiation of air flow through the ionising chamber.

6. A device as claimed in any one of the preceding claims wherein the device also incorporates a trigger to initiate operation, and operation of the trigger initiates supply of air to flow through the ionising chamber.

7. A device as claimed in any one of the preceding claims wherein the resistors are potted in electrically insulating potting compound.

8. A device as claimed in any one of the preceding claims wherein the resistors are within a handle of the device.

Fig.1.


1
2
3
4
AIR
AIR
COMPRESSOR
9
7
5
+
-
HIGH VOLTAGE DC
POWER SUPPLY
6
+ -
+ -
+ -
10
~
8

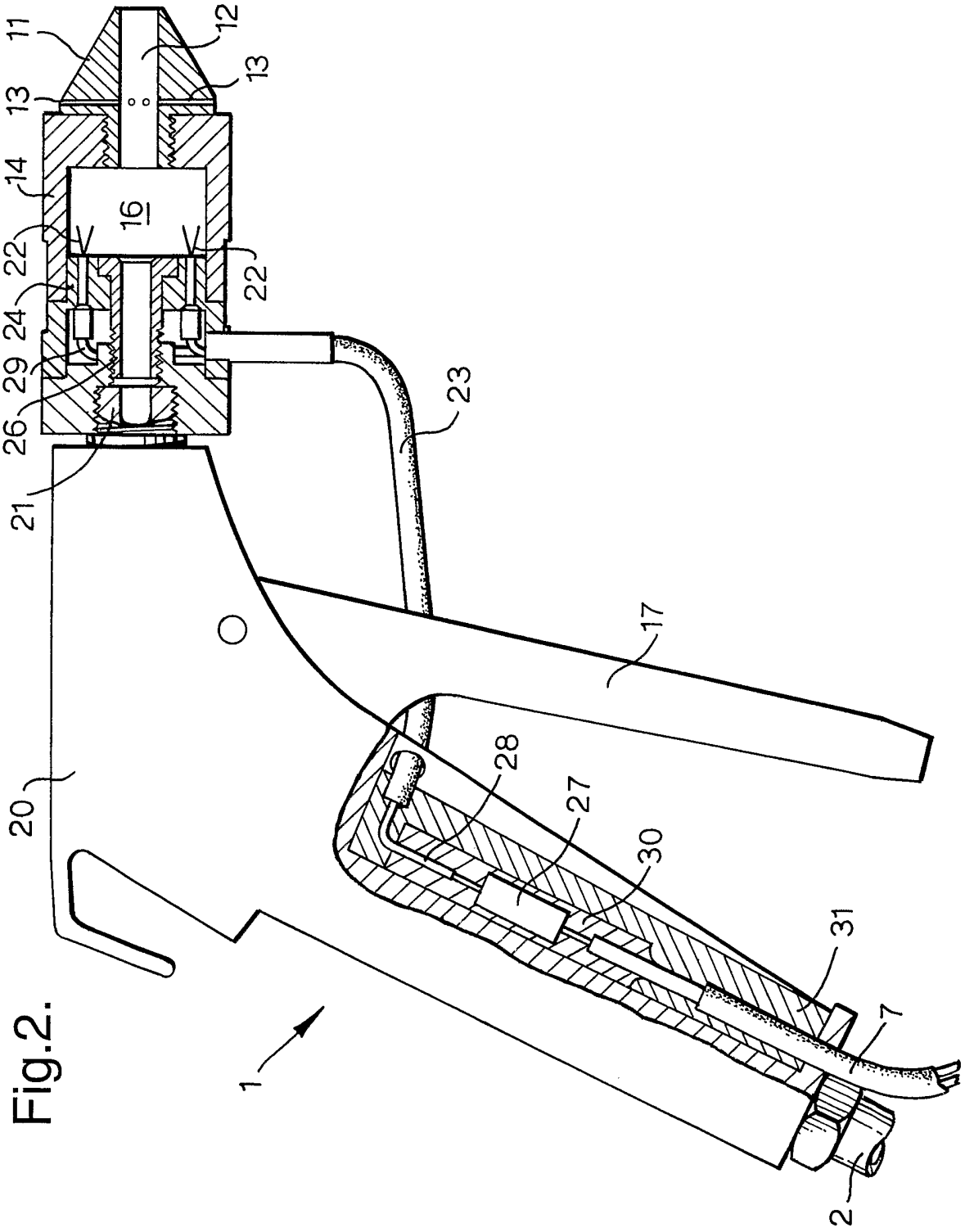


Fig.2.